Can we distinguish an MSSM Higgs from a SM Higgs at a Linear Collider?[1]

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Abstract. We study the prospects for distinguishing the CP-even Higgs boson of the minimal supersymmetric extension of the Standard Model (MSSM) from the Standard Model (SM) Higgs boson by measuring its branching ratios at an e^+e^- linear collider. The regions of the $M_A - \tan\beta$ plane in which an MSSM Higgs boson can be distinguished from the SM Higgs boson depend strongly upon the supersymmetric parameters that enter the radiative corrections to the Higgs mass matrix and the Higgs couplings to fermions. In some regions of parameter space it is possible to extract the supersymmetric correction to the relation between the b quark mass and its Yukawa coupling from Higgs branching ratio measurements.

Present knowledge of the radiative corrections to the Higgs sector of the minimal supersymmetric extension of the Standard Model (MSSM) allows one to compute the branching ratios (BRs) of the MSSM Higgs bosons with high precision. The BRs of the Standard Model (SM)-like Higgs boson of the MSSM (i.e., the MSSM Higgs boson with the largest couplings to WW and ZZ, denoted H_{MSSM}) in general differ from those of a SM Higgs boson (denoted H_{SM}) of the same mass. If these BRs are measured to high enough precision, they can be used to distinguish between H_{SM} and H_{MSSM}. In this talk we examine the potential of Higgs BR measurements at a future e^+e^- linear collider (LC) to distinguish H_{MSSM} from H_{SM} in various regions of MSSM parameter space that give rise to significantly different behaviors of the MSSM Higgs bosons. For the details of our analysis see Ref. [1].

At tree level, the MSSM Higgs sector depends on only two parameters, M_A and $\tan\beta$. Radiative corrections to the Higgs mass matrix and vertex corrections to the Higgs-fermion Yukawa couplings introduce significant dependence on other MSSM parameters (for a review and references see Ref. [2]). The radiative corrections to

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TABLE 1. MSSM parameters in TeV for the three benchmark scenarios. We set the gaugino mass parameter $M_2 = 0.2$ TeV.

Benchmark	μ	$X_t \equiv A_t - \mu \cot\beta$	A_b	M_S	$M_{\tilde{g}}$
No Mixing	-0.2	0	A_t	1.5	1.0
Maximal Mixing	-0.2	$\sqrt{6}M_S$	A_t	1.0	1.0
Large μ and A_t	± 1.2	$\mp 1.2(1 + \cot\beta)$	0	1.0	0.5

TABLE 2. Expected fractional uncertainty of BR measurements at a LC for a 120 GeV SM Higgs boson.

	$b\bar{b}$	WW^*	$\tau^+\tau^-$	$c\bar{c}$	gg	$\gamma\gamma$
Ref. [4]	0.03	0.08	0.07	0.15	0.08	0.22
Ref. [5]	0.024	0.054	0.083–0.135	–	0.055	–

the Higgs mass matrix lead to corrections to the mixing angle α for the two CP-even MSSM Higgs bosons, which affect the Higgs couplings to fermions and vector bosons. The vertex corrections to the Higgs-fermion Yukawa couplings (denoted Δ_b for b quarks) primarily modify the Higgs couplings to $b\bar{b}$ and depend on the parameters $\mu M_{\tilde{g}}$ and μA_t and the squark masses. Explicit formulae may be found in Refs. [1,2].

We examine three benchmark scenarios (Table 1) that lead to very different behaviors for H_{MSSM}. These scenarios are chosen so that the Higgs mass is above its present upper bound from LEP and to maximize the effect of the choice of MSSM parameters on the behavior of the Higgs BRs. We use the program HDECAY [3] to which we have added the Yukawa vertex corrections. In each of the benchmark scenarios we compute the mass and BRs of H_{MSSM} at each point in the $M_A - \tan\beta$ plane. We compare the BRs of H_{MSSM} to those of H_{SM} with the same mass and plot contours of $\delta BR \equiv |BR_{MSSM} - BR_{SM}|/BR_{SM}$. In Table 2 we show the expected uncertainties of BR measurements at a LC for a 120 GeV SM Higgs boson from Refs. [4] ($\sqrt{s} = 500$ GeV with 200 fb^{-1}) and [5] ($\sqrt{s} = 350$ or 500 GeV with 500 fb^{-1}). In Fig. 1 we plot the 1σ and 2σ contours (based on the uncertainties from Ref. [4] (Table 2)) of $\delta BR(b)$, $\delta BR(W)$ and $\delta BR(g)$ in the three benchmark scenarios.

In the top left panel of Fig. 1 we examine the no mixing scenario. In this scenario the reach in M_A for distinguishing H_{MSSM} from H_{SM} is fairly independent of $\tan\beta$. With the uncertainties in Ref. [4] (Table 2), $BR(g)$ gives the greatest reach in M_A, allowing one to distinguish H_{MSSM} from H_{SM} at 1σ (2σ) for $M_A \lesssim 725$ GeV (475 GeV).

In the top right panel of Fig. 1 we examine the maximal mixing scenario. In this scenario we find significant deviations in $BR(b)$ and $BR(g)$ from their SM values even at very large $M_A > 1$ TeV. We find that one can distinguish H_{MSSM} from H_{SM} at 1σ using $\delta BR(g)$ even for $M_A \simeq 2$ TeV, while at 2σ the reach in $\delta BR(g)$ and $\delta BR(b)$ are comparable and one can distinguish H_{MSSM} from H_{SM} for $M_A \lesssim 650$
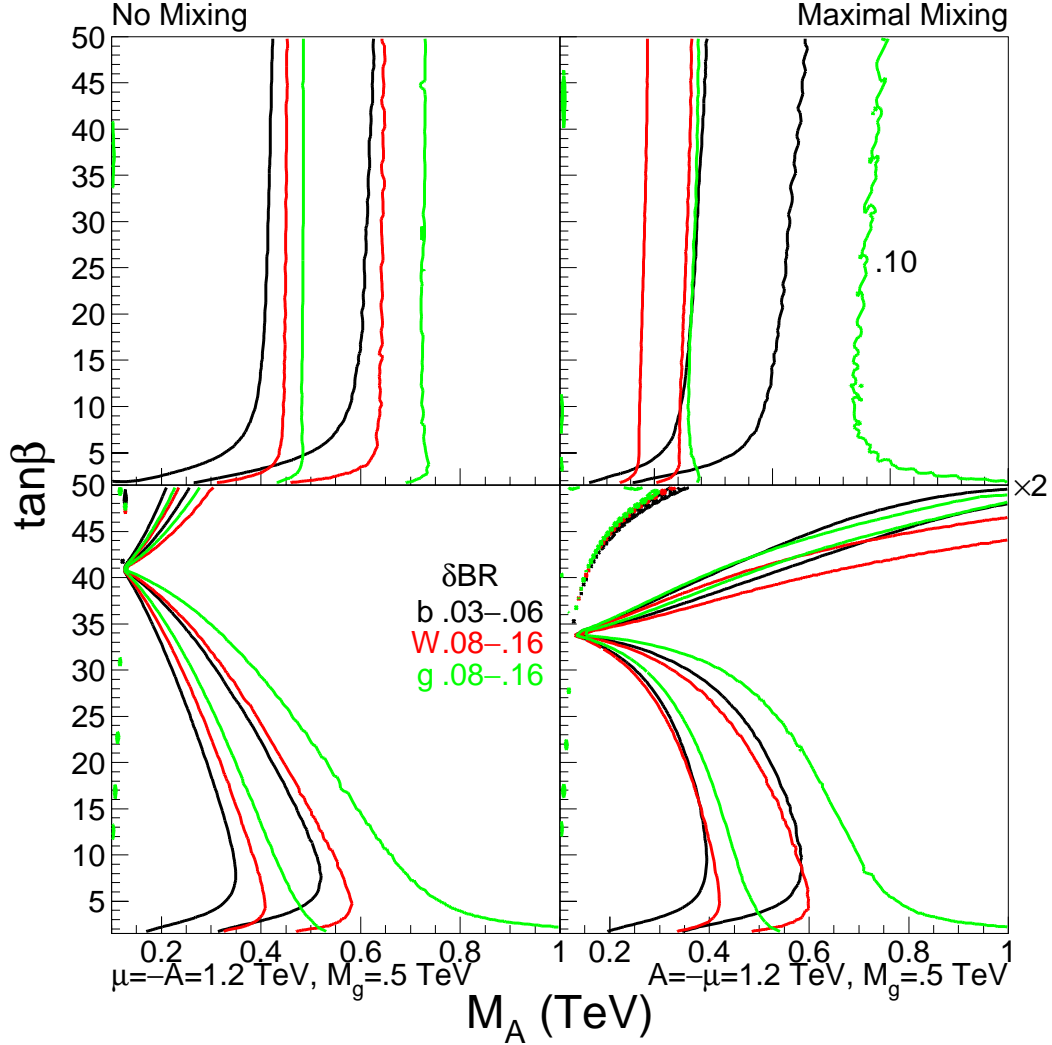
FIGURE 1. The 1σ and 2σ contours of $\delta BR(b)$ (black), $\delta BR(W)$ (red or dark gray) and $\delta BR(g)$ (green or light gray) in the no mixing scenario (top left), the maximal mixing scenario (top right), and the large μ and A_t scenario with $\mu = -A_t = 1.2$ TeV (bottom left) and $\mu = -A_t = -1.2$ TeV (bottom right). In the maximal mixing scenario (top right) we plot M_A between 0.1 and 2 TeV and $\delta BR(g) = 0.16$ and 0.10 (here $\delta BR(g) = 0.08$ lies above $M_A = 2$ TeV).

GeV.

In the two bottom panels of Fig. 1 we examine the large μ and A_t scenario. In this scenario we find that at large $\tan\beta$ there are regions of parameter space in which H_{MSSM} cannot be distinguished from H_{SM} even for very low values of $M_A \simeq 200$ GeV. Thus the regions of the $M_A - \tan\beta$ plane in which H_{MSSM} can be distinguished from H_{SM} depend strongly on the supersymmetric parameters.

Finally, in Ref. [1] we show that it is possible to extract Δ_b from measure-
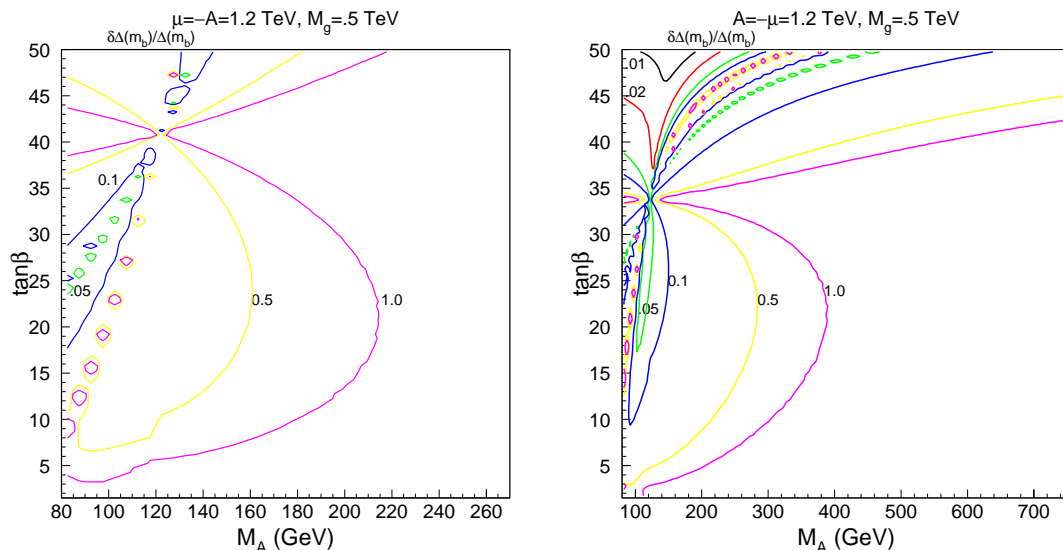
FIGURE 2. Contours of the fractional error in the determination of Δ_b in the large μ and A_t scenario. Here $\mu = -A_t = 1.2$ TeV (left) and $\mu = -A_t = -1.2$ TeV (right).

ments of ratios of branching ratios: $\Delta_b = (1 - \sqrt{x})/(\sqrt{x} - \sqrt{y})$ with $x = (BR(b)/BR(\tau))/(BR(b)/BR(\tau))_{SM}$ and $y = (BR(c)/BR(\tau))/(BR(c)/BR(\tau))_{SM}$. In Fig. 2 we show the fractional error in the determination of Δ_b from measurements of $BR(b)/BR(\tau)$ and $BR(c)/BR(\tau)$ in the large μ and A_t scenario (see Table 1), in which Δ_b is quite sizeable. We assume BR uncertainties as in Ref. [4]. Note that for $\mu > 0$ (the left panel of Fig. 2), Δ_b can only be distinguished from zero for moderate to large $\tan\beta$ and $M_A \lesssim 170$ GeV. In contrast, for $\mu < 0$ (the right panel of Fig. 2), Δ_b can be determined with 10% accuracy even for M_A as large as 600 GeV for large $\tan\beta$. This measurement of Δ_b may ultimately be combined with other measurements to determine the underlying SUSY parameters.

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